Operational Oceanography and European Environment Agency indicators

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Abstract

Operational Oceanography (OO) emerged to a stage of development that allows the design and development of services such as the routine production of environmental and climate indicators for specific users. Indicators are synthetic indices of environmental changes at various time scales. The indicators are often used by international environmental agencies and national directorates like the European Environment Agency (EEA web page on indicators: http://themes.eea.europa.eu/indicators/) and by the regional Conventions (i.e. Helcom webpage on indicators: http://www.helcom.fi/environment2/ifs/en_GB/cover/). In this paper we have carried out an analysis on the possible improvements of existing indicator reporting in use by EEA and on the development of new indicators based on OO products. The list of indicators includes: Temperature, Chlorophyll-a (from ocean colour), Ocean Currents and Transport, Salinity, Transparency, Sea Level, Sea Ice and Density. A critical analysis has been carried out to identify the relevance of the above mentioned indicators for EU policies, their spatial and temporal coverage, their accuracy and their availability. The Temperature and Chlorophyll-a (Chl-a) products are the most suitable for an indicator development test phase. In particular the OO Chl-a product, deduced from satellite data, will be able to contribute to the further development of the EEA Chl-a indicator that is based on in-situ measurements (CSI023). Sea Level and Sea Ice products are also robust quantities for climate indicators. For the above mentioned indicators a development test phase has been undertaken in 2008 within the European Topic Center for Water (ETC-W) and BOSS4GMES (http://www.mersea.eu.org/Indicators-with-B4G.html) projects. Ocean Currents and Transports and Salinity products appear less mature for the development of new

indicators at pan-European level because their connection with environmental aspects are less recognised in all European marine areas, to be noted that Transport derived indicators are available in the Norwegian Sea and in the North Sea where correlation with ecosystem components have been shown. Transparency product appears suitable for indicator production, but more effort should be put to relate the indicator to in-situ measurements. In addition to the products mentioned above, we have also identified a Density indicator that appears relevant for the eutrophication problems and ecosystem health.

Keywords: indicators, reporting, operational oceanography

1. Introduction

Operational Oceanography (OO), such as to be implemented by MyOcean, will be at the basis of the GMES (http://www.gmes.info) Fast Track Service, notably the Marine Core Service (MCS) for the protection and management of the marine environment. This paper examines the Spatial Data Theme Elements (SDTE) produced by the OO services that can contribute to the development of indicators for EEA. SDTE are defined following the INSPIRE Directive and are ocean state variables with specified spatial and temporal resolution. The usage of "SDTE" nomenclature should help to distinguish between SDTE such as "Temperature" and the derived set of indicators. For some of the OO SDTE we present the data and products availability (table 1). These STDE are chosen among those indicated by EMMA (European Marine Monitoring and Assessment) (EEA-led EMMA OO Workshop final report, 2006). On the basis of the accuracy and availability, we have also ranked the priority of the SDTE for indicator development.

Spatial data theme element (STDE)	Suitability for future indicator[1]	Spatial coverage[2]	Availability[5]	Source[6]	Accuracy[4]	Temporal coverage[3]	Priority ranking[7]
Temperature	High	All	Yes	IO M EO	High High High	1871 -present time 2000- present time 1985- present time	2
Chlorophyll-a	High	All	Yes	EO	High	1980-1986 and 1997-present time	1
Ocean Currents	Moderate	NE Atl., North Sea, Baltic Sea, Med. Sea	2009	M	Moderate	2000- present time	6
Salinity	Moderate	NE Atl., North Sea, Baltic Sea, Med. Sea	Yes	M IO	High High	2000- present time 1900-present time	7
Transparency	High	All	2009	SO	Moderate	1997- present time	3
Sea level	High	All	Yes	IO M EO	High	1900-present time 2000-present time 1992- present time	4
Ice	High	Artic Oc., Baltic Sea	Yes	M, EO	High	1979- present time	5

Table 1: Summary of the state of development of the STDE analyzed in this paper. (Notes: 1-A subjective scale low, moderate, or high has been used; 2- Seas: Global, NE Atlantic, North Sea, Baltic Sea, Mediterranean, Black Sea, Artic Ocean. 3- The longest period covered is mentioned;

4- A subjective scale low, moderate, or high has been used; 5- “yes” has been used or alternatively the year when product will start has been indicated; 6- M means Model, IO means In-situ Observations, EO means Earth Observation from satellite; 7- Spatial data theme elements have been prioritize in the order 1-7.

2. Indicators definition and preliminary results

Indicators provide information on matters of wider significance than what is actually measured or make perceptible a trend or phenomenon that is not immediately detectable (Hammond et al., 1995). Environmental indicators reflect trends in the state of the environment and monitor the progress made in realising environmental policy targets and provide insight into the state and dynamics of the environment (Smeets and Weterings, 1999).

Environmental indicators are synthetic values extracted from a relevant SDTE: they should be subdivided into ranges of values which correspond to the assessment of a qualitative state of the environment. For each SDTE in Table 1 we have started to develop a relevant indicator for EEA.

2.1 *Temperature SDTE and indicator*. SST from OO SDTE products provides high frequency and complete spatial coverage for the global ocean and the regional seas. In-situ surface data are of large importance to validate satellite data and to increase the accuracy of the combined satellite and in-situ dataset and provide, together with model analysis, information on entire water column. Presently EEA is using Sea Surface Temperature timeseries in the Climate change and assessment reports and an indicator related to the Global and European Temperature (CSI 012) exists and shows trends in annual average global and European temperature and European winter/summer temperatures for land and ocean together. Temperature related indicators can answer policy-relevant questions such as: will the global average temperature increase stay within the EU policy target (2 degrees C above pre-industrial levels)? This question is related to the Council Decision (2002/358/EC) of 25 April 2002 and Decision No 280/2004/EC of the European Parliament and of the Council of 11 February 2004.

Different indicators related to the ocean temperature can be derived from the OO temperature SDTE. A first set is related to SST where the longest time series are available (1871-today). The inclusion of regional high resolution satellite datasets for several European Seas started with the 2008 EEA and JRC Climate Change Impacts Report (in press) and should continue. Additional indicators are possible to be developed that consider the whole water column temperature and that could be indicative of long term effects and extreme events. The latter are very relevant for ecosystems dynamics and possible stresses (Real time SST anomalies maps with time scales from daily to monthly, annual basin average Heat Content (HC) anomalies from approximately 1985-today, HC linear trends and maps of the spatial distribution of HC linear trends from 1985-today, real time temperature anomaly profiles in the water column, mixed layer depth anomalies time series).

An example is given for the Temperature indicator in Figure 1. The Sea Surface Temperature anomaly basin mean has been calculated for the Mediterranean Sea using the daily analysis of the Mediterranean Forecasting System compared with the MEDATLAS climatology. The model analysis timeseries covers the period 2001-today. The SST anomaly indicator is able to detect high SST anomaly such as the ones that occurred in 2003 and that causes environmental stresses (De Bono, 2006).

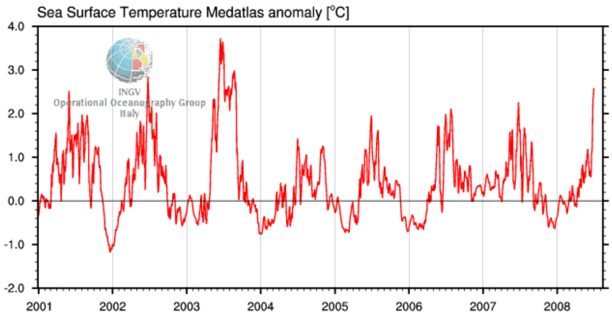

Figure 1: Mediterranean daily Sea Surface Temperature anomaly basin mean calculated from MFS analysis with respect to MEDATLAS climatology (produced by INGV) http://www.mersea.eu.org/Indicators-with-B4G.html

2.2 Chl-a SDTE and indicator. The SDTE related to Chl-a is a well developed satellite product and it is now widely available at daily and monthly time scales in all European coastal/shelf and open ocean waters (higher temporal resolution can be achieved in southern European regional seas). OO Chl-a products are derived from all available satellite sensors and cover the periods 1980-1986 and 1997 to the present. The former dataset, however, will be difficult to include in the indicators production. The relevant EEA indicator for Chl-a is the CSI023 (Chlorophyll in transitional, coastal and marine waters - Core Set of Indicator n°023:

http://themes.eea.europa.eu/IMS/IMS/ISpecs/ISpecification20041007132031/full_spec) which evaluate the trends of Chl-a for seasonal (June to September for stations north of 59 degrees in the Baltic Sea (Gulf of Bothnia and Gulf of Finland) and from May to September for all other stations) mean of chl-a from in-situ collected samples, integrated in the first 10 meters. The objective of the CSI023 indicator is to demonstrate the effects of measures taken to reduce discharges of nitrogen and phosphate on coastal concentrations of phytoplankton expressed as chlorophyll-a. This is an indicator of eutrophication. This indicator is relevant for all the EU Directives aimed at reducing the loads and impacts of nutrients (i.e.: Nitrates Directive (91/676/EEC), Urban Waste Water Treatment Directive (91/271/EEC)).

In order to include indicators from Chl-a SDTE OO derived products for Chl-a into the CSI 023, we are studying the different morphological and hydrological structure of European regional areas identifying shelf, coastal and deep ocean water areas and classify them into ‘Chl-a areas’. The new Chl-a indicator could then be: a) Analyses of summer period mean in the different Chl-a areas to detect trends as it is done for CSI023, b) Monthly mean anomaly time series of Chl-a averaged in the different coastal, shelf and deep ocean areas of the European seas; c) Spatial and temporal linear trends of Chl-a seasonal and monthly mean anomalies; d) Real time Chl-a anomaly maps (time scale can range from daily to monthly). Moreover intercalibration of CSI 023 indicator with OO Chl-a derived product will be carried out.

2.3 Ocean Currents and Transports SDTE and indicator. Ocean Currents and Transports SDTE are now produced by OO allowing for estimation of transboundary currents, water exchanges and residence time. These could be turned into indicators and related to marine ecosystem functioning and changes. In the North Sea/Norwegian Sea such correlation has been shown to be relevant for the size of the horse mackerel stock, but this correlation with environmental and ecosystem aspects is not yet well developed in other European marine areas.

2.4 Salinity SDTE and indicator. Salinity SDTE will allow estimating indirectly the changes in evaporation-precipitation, ice sheet and glacier melting and river-run-off (also due to human impacts). Using OO products, salinity indicators could be developed to monitor the changes in salinity all over the European Seas. Several indicators could be developed such as annual and basin average surface salinity anomalies, surface salinity linear trends of the period and maps showing the spatial distribution of salinity linear trends. Moreover real time salinity anomalies maps and real time salinity anomaly profiles in the water column can be produced.

2.5 Transparency SDTE and indicator. Water transparency can be estimated with Ocean Colors images by estimating the K (490) values together with and Case I and Case II water flags. Transparency SDTE is suitable to derive indicators in support the water quality monitoring (i.e. European Directive 76/160/EEC on Bathing Water Quality). Similarly to the Chl-a indicators it is recommended to develop transparency indicators based upon the different morphological and hydrological structure of European regional areas, identifying shelf, coastal and deep ocean water areas. The new transparency indicators could then be: a) monthly mean anomaly time series of transparency averaged in the different coastal, shelf and deep ocean areas of the European seas; b) spatial and temporal linear trends of transparency seasonal and monthly mean anomalies; c) real time transparency anomaly maps (time scale can range from daily to monthly).

2.6 Sea level SDTE and indicator. This Sea Level SDTE is derived from two main observational data streams: the sea level stations dataset and the satellite altimetry dataset. Whereas the in-situ sea level measurements is a unique mean to provide the longest timeseries of sea level measurements dating back to late 1800, accurate estimation of the sea level trend and its associated spatial structure are estimated for the last 17 years thanks to satellite altimetry. OO has already organized the production and visualization of Sea level trend indicators from altimetry at different space and time scale (AVISO web site: http://www.aviso.oceanobs.com/en/news/ocean-indicators/mean-sea-level/index.html). In the past EEA had used only insitu data to estimate sea level trends for the last century. Starting from the last EEA climate change and impacts report EEA has started to include OO altimetry data.

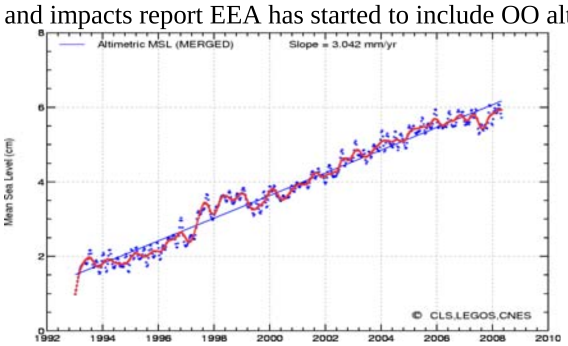

Figure 2: Global mean sea level since October 1992 as seen by the altimetry satellites. Seasonal variations have been removed. These data are corrected from Inverse barometer effects, but not from Post-glacial rebound ones. (Produced by *Cnes*/*CLS*/*Legos*).

One example is proposed in figure 2: the global MSL, this shows the increase of sea level around 3.042 mm/years in the last 17 years.

2.7 Sea ice SDTE and indicator. Observed changes in the extent of Arctic sea ice, detected by ice indicators, provide early evidence of global climate warming. The indicators derived from the Ice SDTE describe the trends of the area covered by the ice (record low summer ice area in the Arctic timeseries and trends, Icea Area and Extent timeseries and trends and anomalies). Examples are available at http://www.mersea.eu.org/Indicators-with-B4G.html

2.8 Density SDTE and indicator. The 'stratification-stability' indicator is a derived quantity from the density profiles deduced from temperature and salinity data and could be calculated using the Brunt-Vaisala frequency which is a measure of stability of the water column. This indicator appears relevant for the eutrophication problems and ecosystem health and can contribute to the Water Framework Directive characterization of coastal waters at pan-European level.

3. Discussion

Chl-a SDTE appears ready to be used and an indicator development test phase has started. The OO Chl-a STDE, deduced from satellite data, should be able to contribute to the further development of the EEA CSI-23 Chl-a indicator based on in-situ datasets improving its representativeness for European coastal waters.

Temperature SDTE is a mature and multiple source data set in OO. Its estimates come from multiple data sources, such as satellite, in-situ measurements and models. Quality of the OO products for this SDTE is high (most of the time less than 0.5 deg C). SST from OO SDTE products allows a high frequency and complete global to regional coverage and they are of significant value for climate change monitoring. New indicators could be extracted from the deep temperature OO products.

Sea Level SDTE is well developed and climate indicators have been deduced. In-situ and satellite sea level data give a reliable and accurate estimate of sea level SDTE and indicators can be produced from them. A climate change indicator derived from Sea Level SDTE is the MSLT.

Sea Ice SDTE, from model and satellite OO products, is also well developed and climate indicators have been developed.

It is believed that the Ocean Current and Transport SDTE are less ready for the development of new indicators at pan-European levels because their relationship with environmental and ecosystem aspects is not yet well developed and quantified for all European Seas. To be noted that is the Norwegian Sea and North Sea, Transport related indicators, correlated with ecosystem components, have been developed.

Even if OO products are available, the Salinity SDTE appears less ready for the development of new indicators at pan-European level because its correlation with environmental aspects is not yet well recognised in all European marine areas.

Transparency SDTE appears ready for an indicator development but more effort should be put to relate the indicator to in-situ measurements (Secchi disk and other measurements).

Finally the Density indicator can be easily evaluated from in-situ and model temperature and salinity STDE products that are commonly produced by OO services. Preliminary investigations should be done to understand the space-time variability of this indicator in European regional shelf areas and the data visualization should be adapted to such variability in space and time.

4. Conclusions

The key SDTEs produced by OO services are considered mature for contribution to the development of several indicators for EEA. Most of the described SDTEs are contributing to the development of pan-European uniform coverage indicators. This paper has documented this and should be at the basis of a demonstration exercise to be carried out in 2008 where the indicators are produced by the OO services. The paper identifies Chl-a and Temperature STDE derived indicators as being the most relevant to be implemented. Sea Level and Sea Ice derived indicators are also well developed. A first example of indicators is given in the following webpage: http://www.mersea.eu.org/Indicators-with-B4G.html

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